Observing Spin Waves

PHAROS

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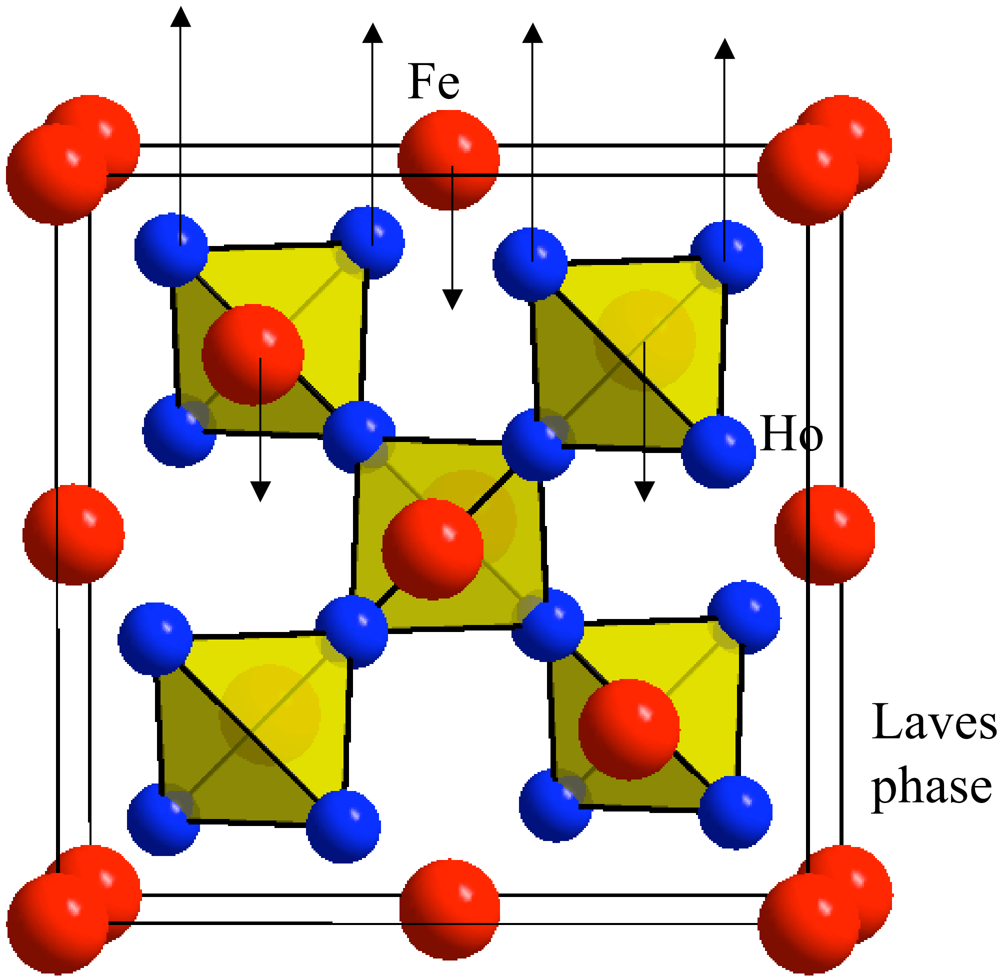
Outline

- What we measured
- Why we measured it
- How we measured it
- Our results

Crystal structure of $HoFe_2$



$HoFe_2$ forms

Cubic Laves

Phase compound

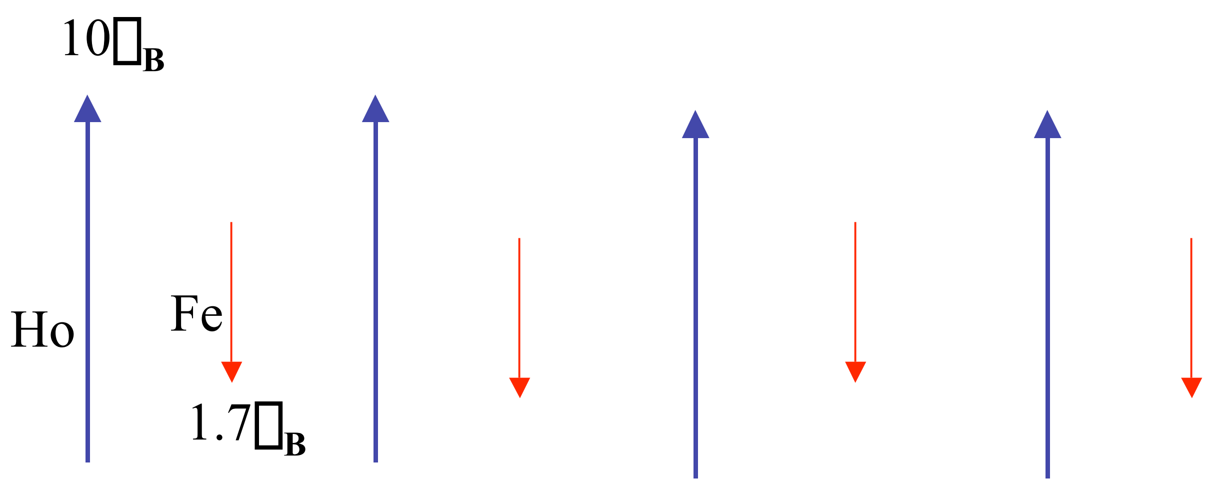
with the easy axis

of magnetization

along the [100]

direction

Ferrimagnetic State



Fe-Fe exchange interaction

Ho-Fe exchange interaction

Ho-Ho exchange interaction

(Weak)

Magnetization of $HoFe_2$

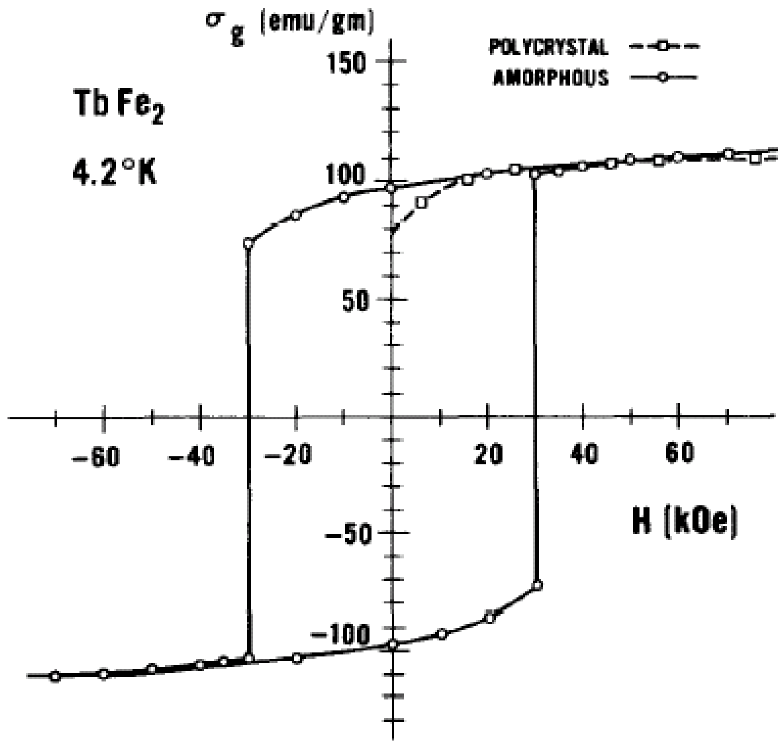


FIG. 2. Hysteresis loop of $TbFe_2$ at 4.2°K.

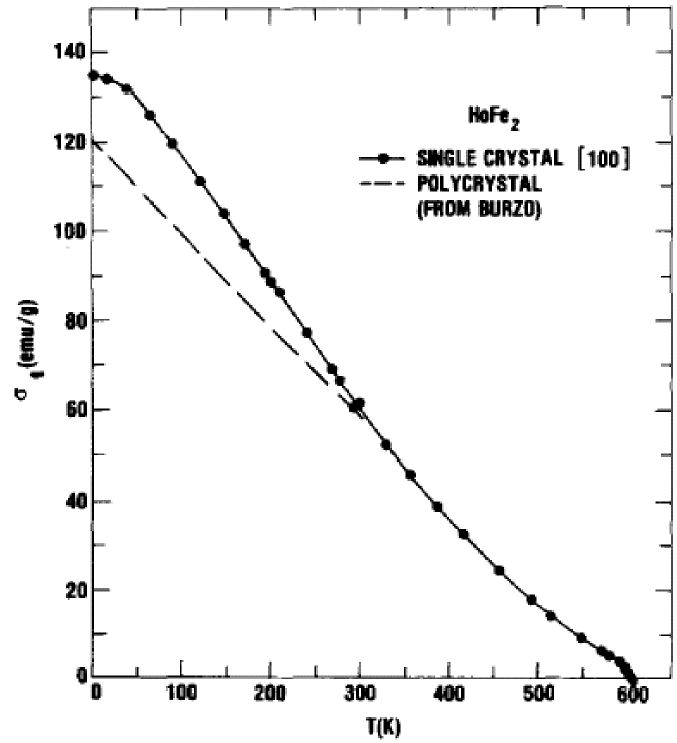


Fig. 3 Spontaneous magnetic moment of single crystal $HoFe_2$ as a function of temperature.

T_c = 606 K for Single crystal

Magnon dispersion relations

$$\hbar\omega_q^{ferro} = S[J(0) - J(q)] \approx Dq^2$$

In cubic symmetry
$D = 2JSa^2$

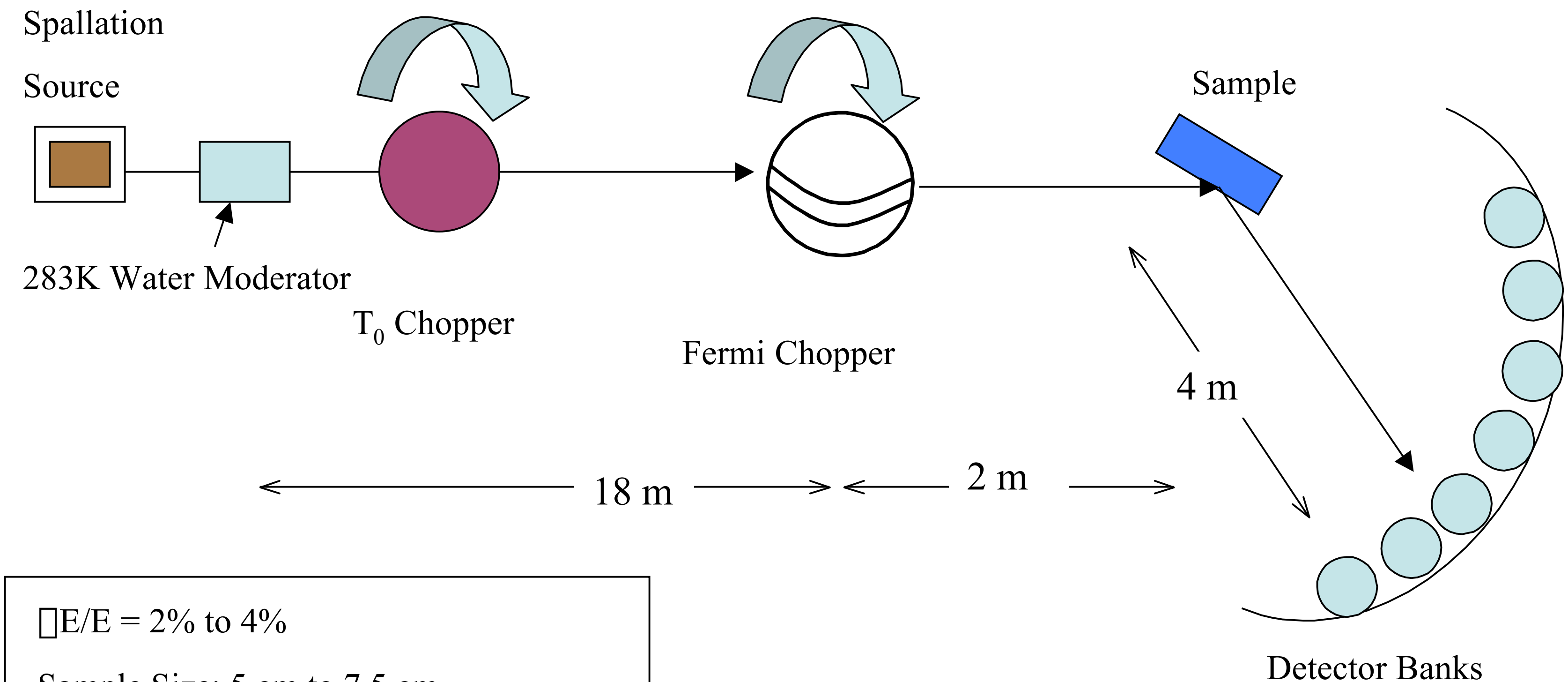
$$\hbar\omega_q^{antiferro} = S\sqrt{J(0)^2 - J(q)^2}$$

where $J(q) = \sum_{i,j} J_{ij} \exp\left\{i\vec{q}.\left(\vec{R}_i - \vec{R}_j\right)\right\}$

$Ho_{0.88}Tb_{0.12}Fe_2$

- Tb goes into the Ho sites
- Curie Temperature, T_c = 610 K
- Inelastic neutron scattering→Magnon Dispersion Relation→direct information on the Exchange Interactions

Pharos Spectrometer



$\Delta E/E$ = 2% to 4%

Sample Size: 5 cm to 7.5 cm

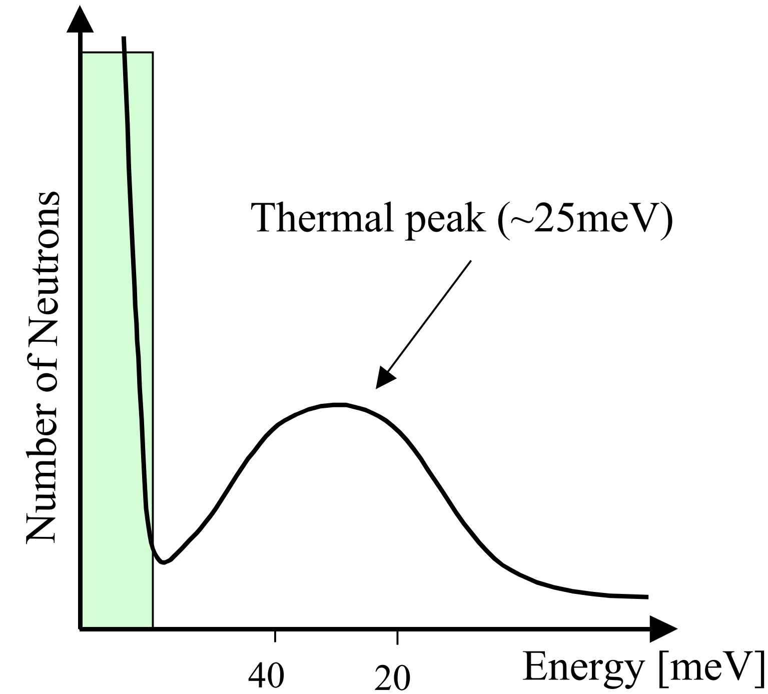
Number of Detectors: 376 He^3 with 40 pixels each

2-Theta : -10^O to 145^O

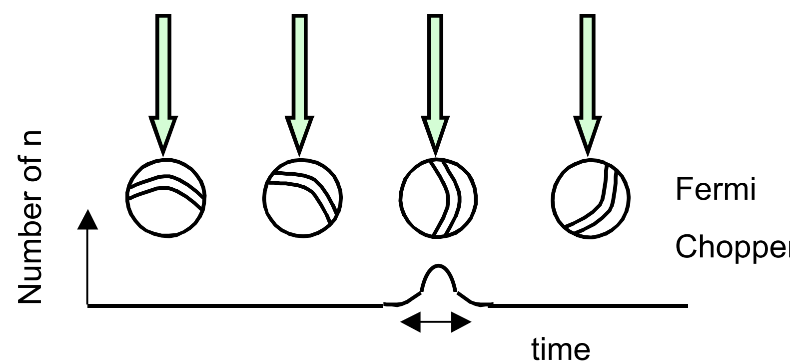
Energy Selection and Resolution

- Fixed Incident Energy
- Scan over Energy Transfers
- Choosing Incident Energy

$$TOF(\mu s/m) = \sqrt{\frac{5.2276 \times 10^{6}}{E(meV)}}$$

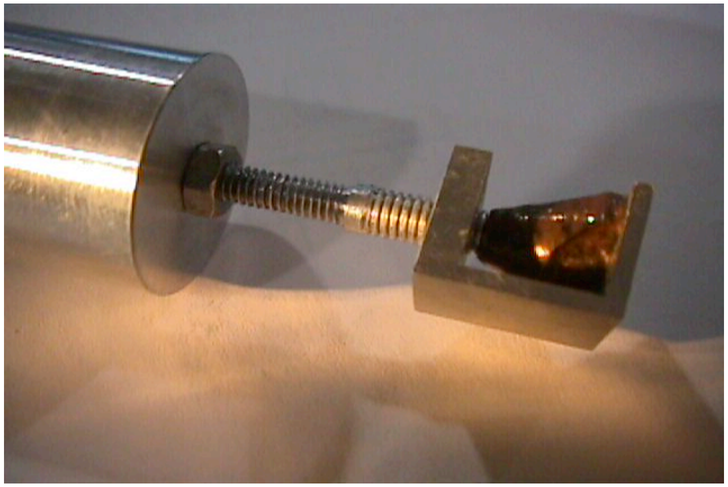


- Phasing of Fermi and T_o choppers
  - For 25meV Time to Fermi Chopper = 8231μs
  - Tune the Frequency of Fermi Chopper to select the Energy Resolution



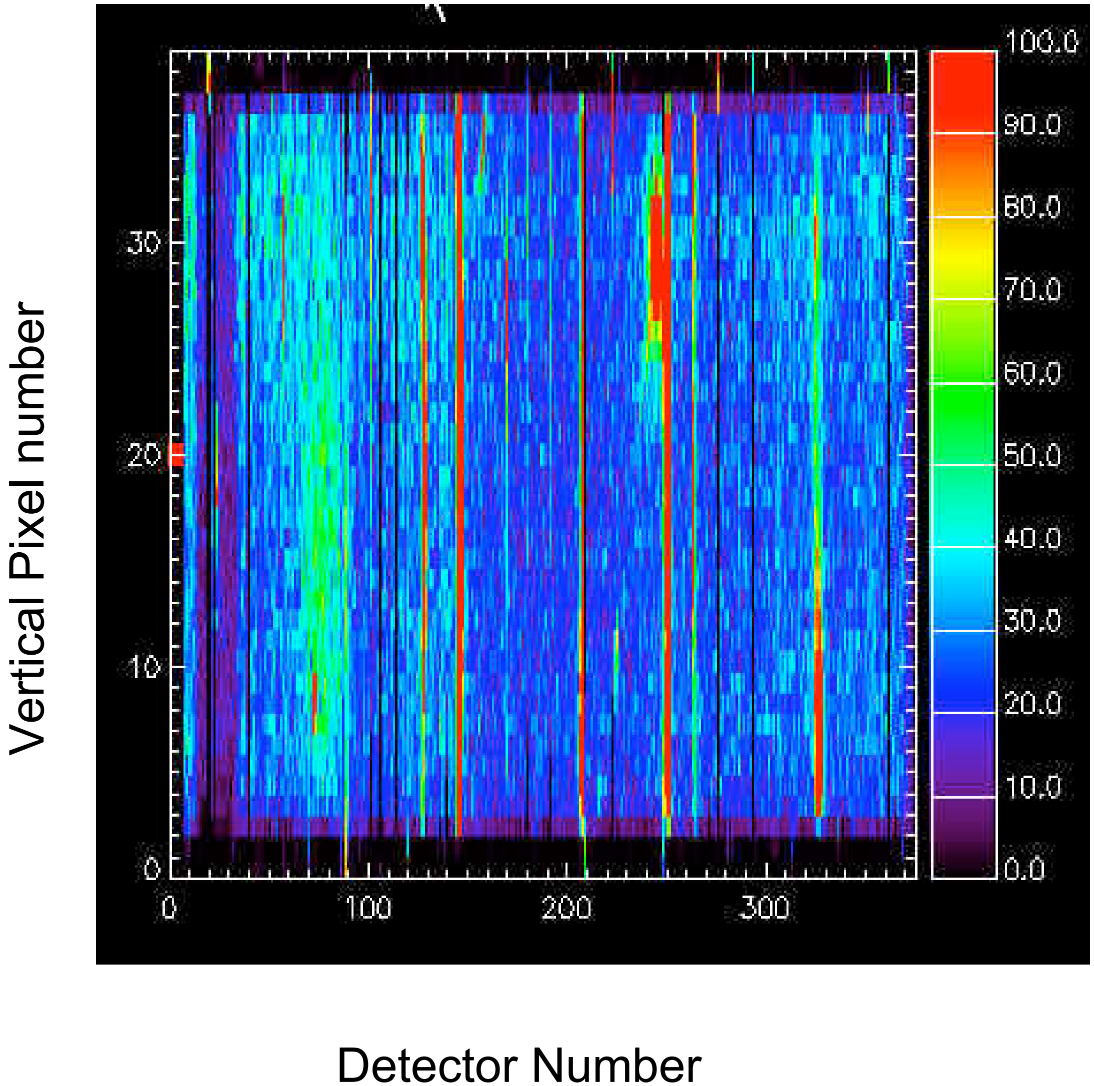
Sample Holder and Alignment

- Experimental Conditions:
  - Evacuated sample environment (reduces air scatter)
  - Versatile sample environment
  - Temperature, pressure, and magnetic field



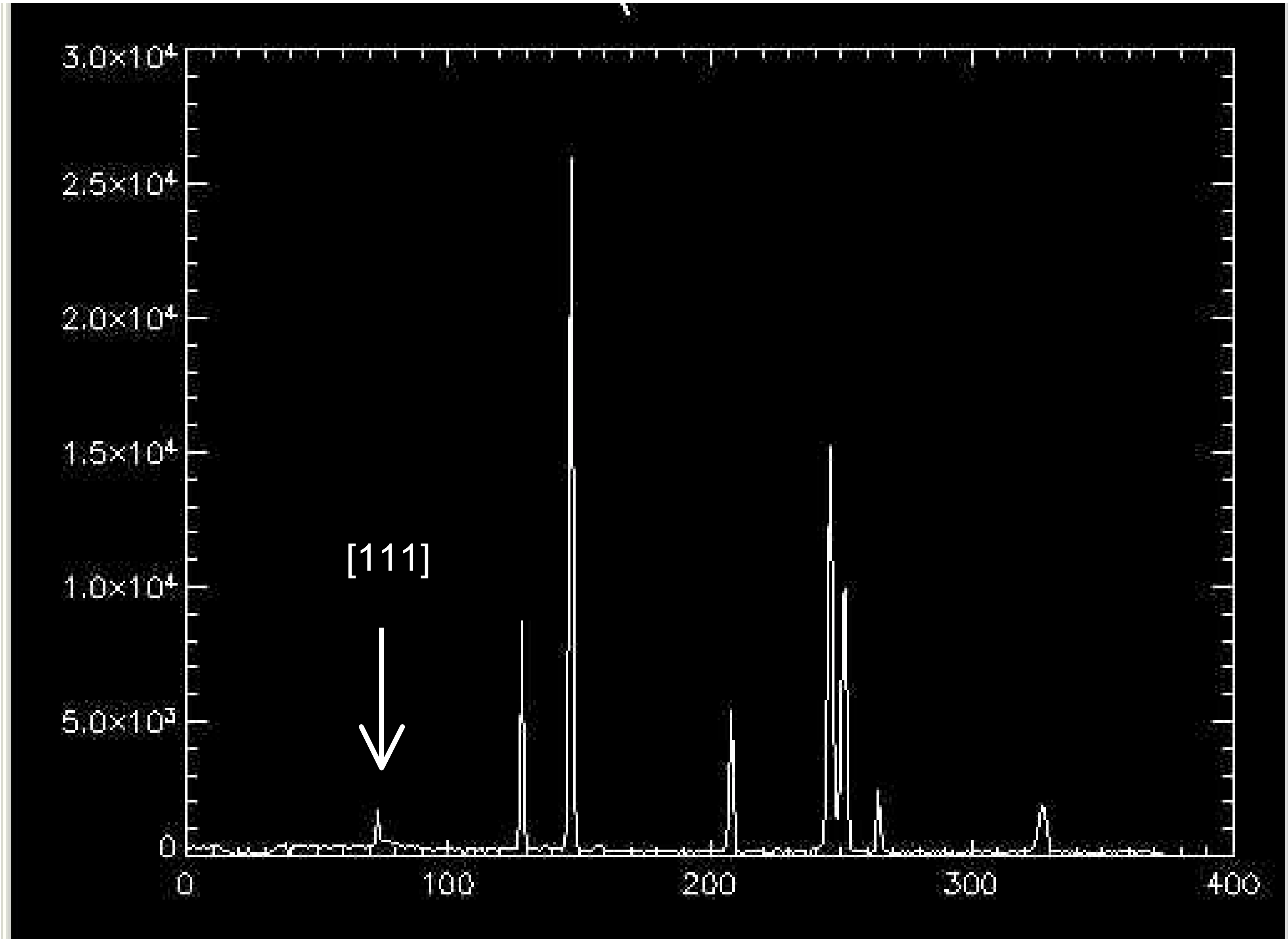
- Sample Mounting and Alignment:
  - Aligned in (1,1,1) with white beam (Fermi Chopper removed)
  - Aluminum sample holder
  - Room temperature experiment
  - 1 day scan

One Slice in Time

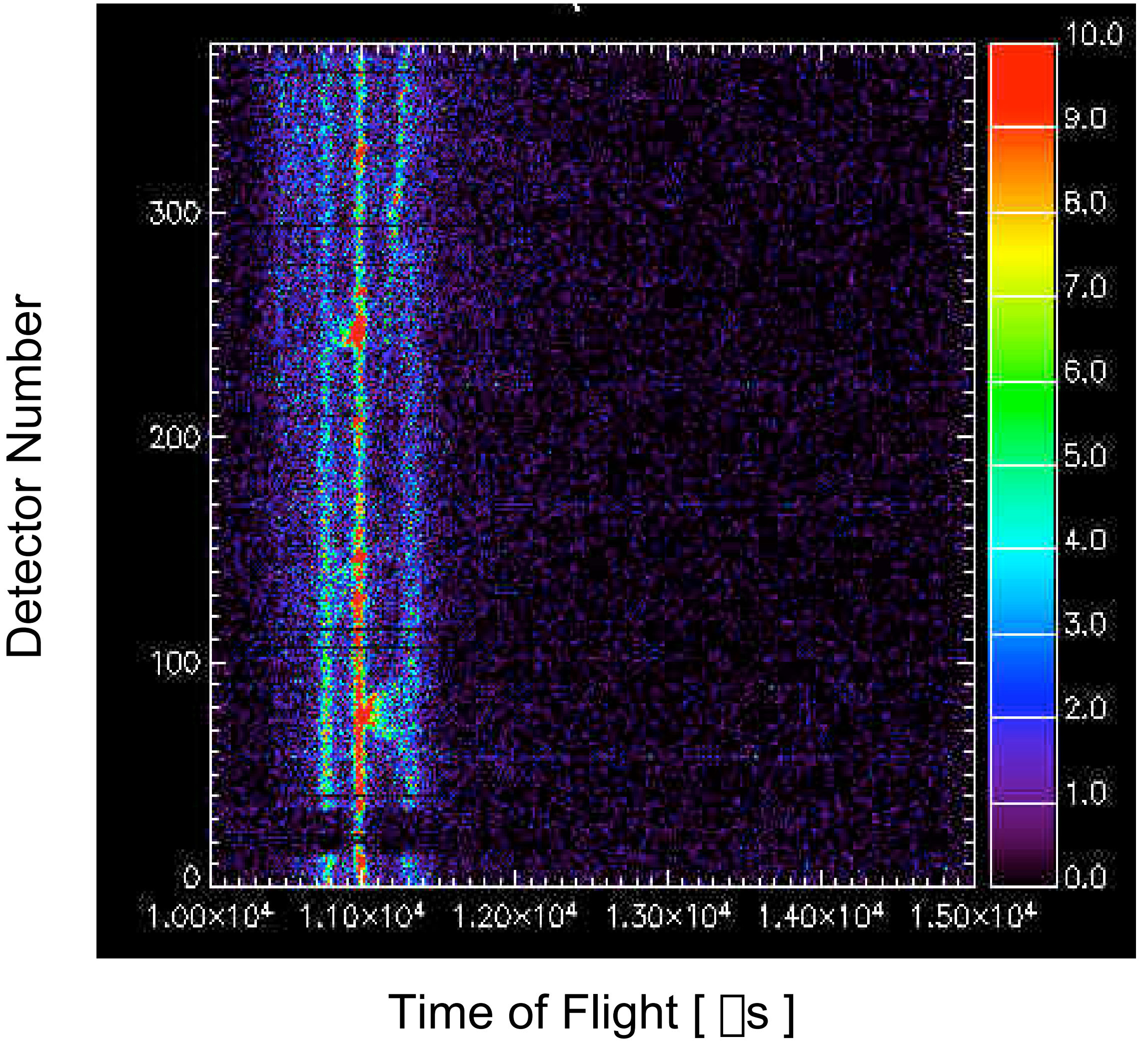


- 40 vertical pixels in each detector bank
- Debye-Scherrer Cones from the aluminum holder intersect at straight lines, at certain angles
- Single crystal sample gives spots

Diffraction Pattern

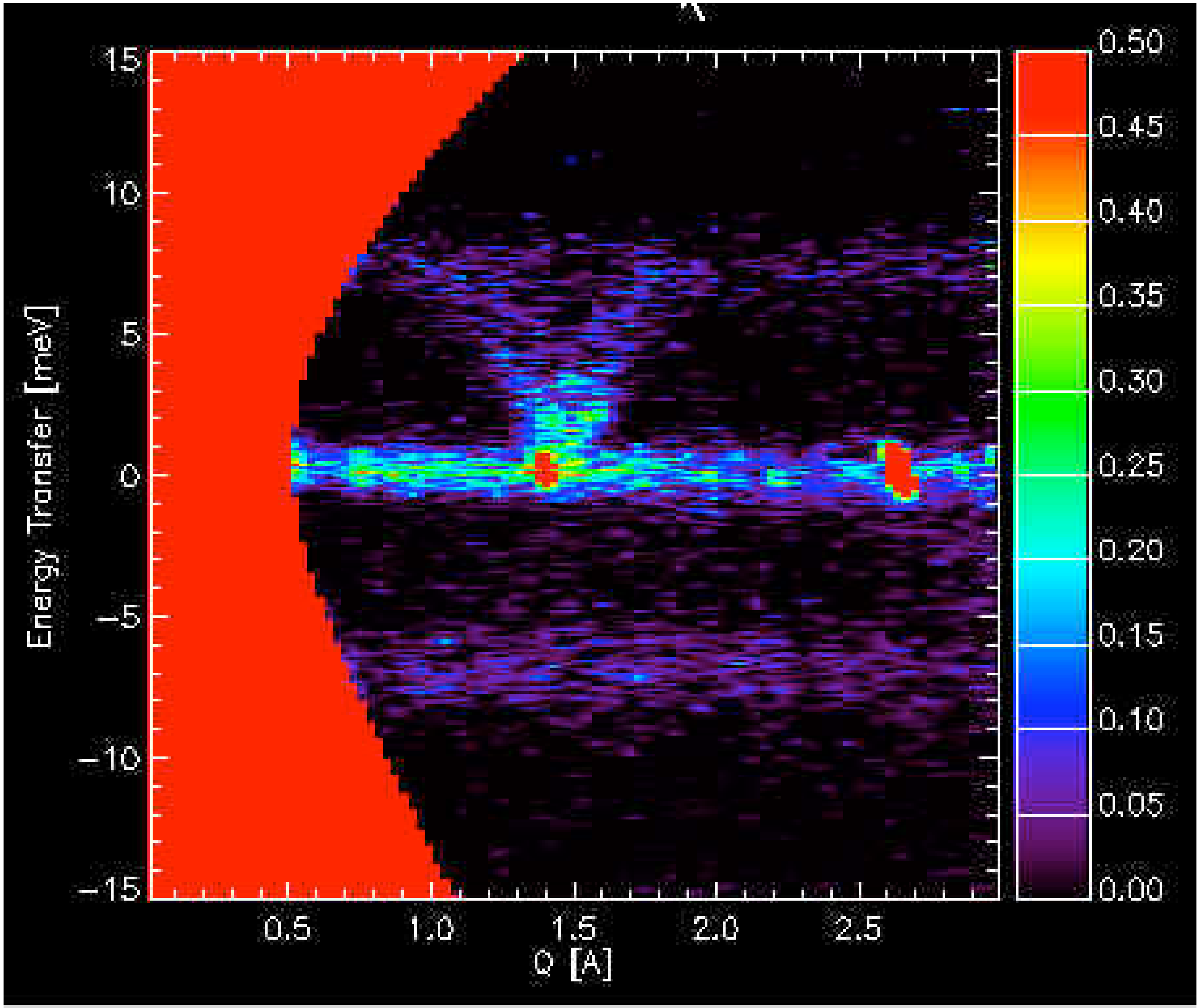


Inelastic vs. Elastic



- Clearly see energy transfer
- Integrated over the 40 pixels in each detector bank
- Imposing a little deviation on 2θ
- Not taking into account that we are interested in a spot

Ahh…Dispersion



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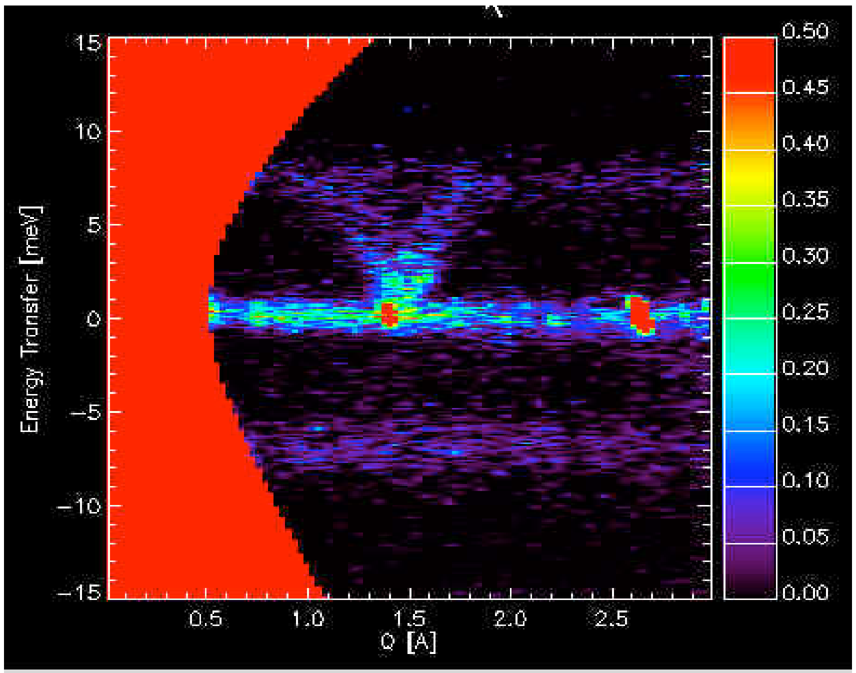


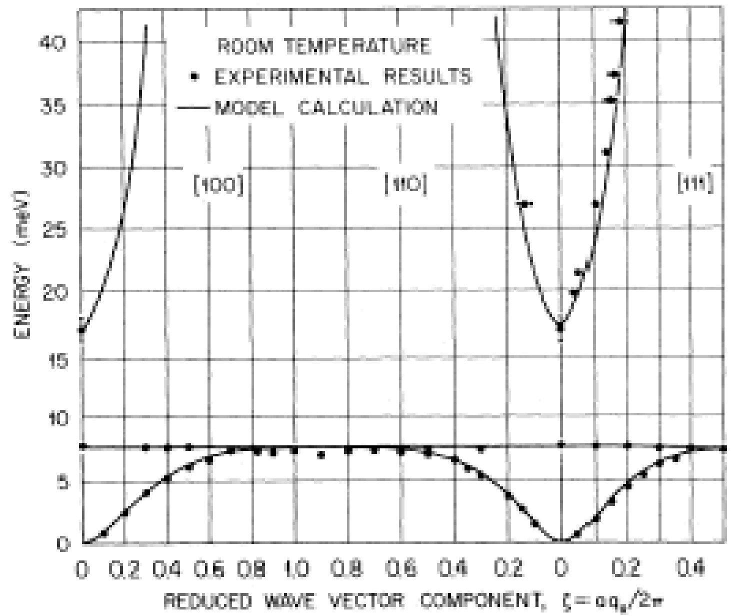


FIG. 1. Magnon dispersion relation for $Ho_{0.88}Tb_{0.12}Fe_2$ measured at room temperature.

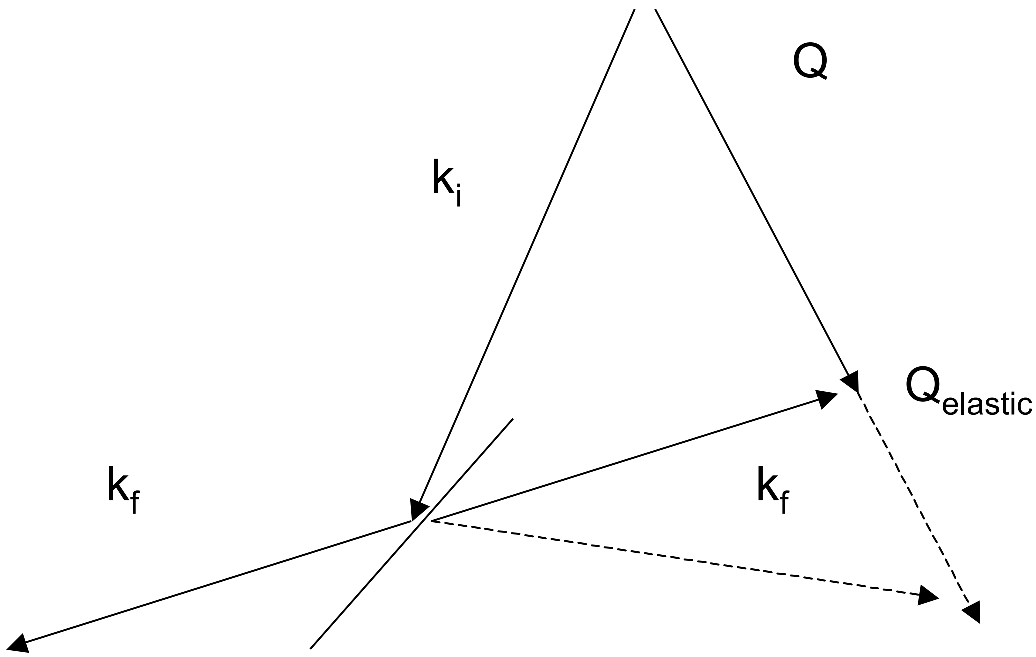
–R. M. Nicklow et al. *PRL* **36**, 532 (1976).

- Excellent Agreement!!!

Conclusions

- Inelastic Neutron Scattering is an excellent probe of fundamental excitations in matter
  - PHAROS offers excellent energy resolution over a wide energy range.
- Our results agree quite well with those previously reported
  - R. M. Nicklow et al. *PRL* **36**, 532 (1976).
  - J.J. Rhyne et al. *Physica* **86-88B**, 149 (1977).

THANK YOU



•The minimum Q to see Energy Gain is at $Q_{elastic}$.